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Technical Memorandum

Project: Caselton Mine and Mill Site

Technical Memorandum

Subject: Treasure Hill (OU-1) Stormwater Runoff Analysis

Date: January 29, 2016

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Section 1: Introduction

This Technical Memorandum (TM) has been prepared by Brown and Caldwell (BC) to support the Caselton Mine and Mill Site Project, specifically the Treasure Hill (OU-1) Feasibility Study (FS), and is included as an attachment to the OU-1 FS Work Plan. Treasure Hill is located southeast of, and topographically above, the Town of Pioche in southeastern Nevada. Hydrologic modeling analyses (i.e., runoff model simulations) were performed as a part of an evaluation of surface water runoff to support the design of remedial surface water management facilities within the OU-1 boundary. Incident precipitation on OU-1 has, during threshold precipitation events, caused waste rock materials to be entrained in the runoff and deposited on streets within the town of Pioche.

1.1 Model Area Description

Stormwater runoff from OU-1 generally flows to the northeast toward Newark Street and then down into Main Street, and onto Ely Street. Figure 1 shows the OU-1 drainage area defined by Sunrise Engineering (SE, 2015) in the Stormwater Capital Improvements Program (CIP) Study performed on behalf of the Town of Pioche (subbasin 88b in the SE CIP study). This area covers approximately 243 acres (0.38 square miles), and includes a subbasin located outside of the OU-1 boundary (designated below, as “Out” with discharge point D4).

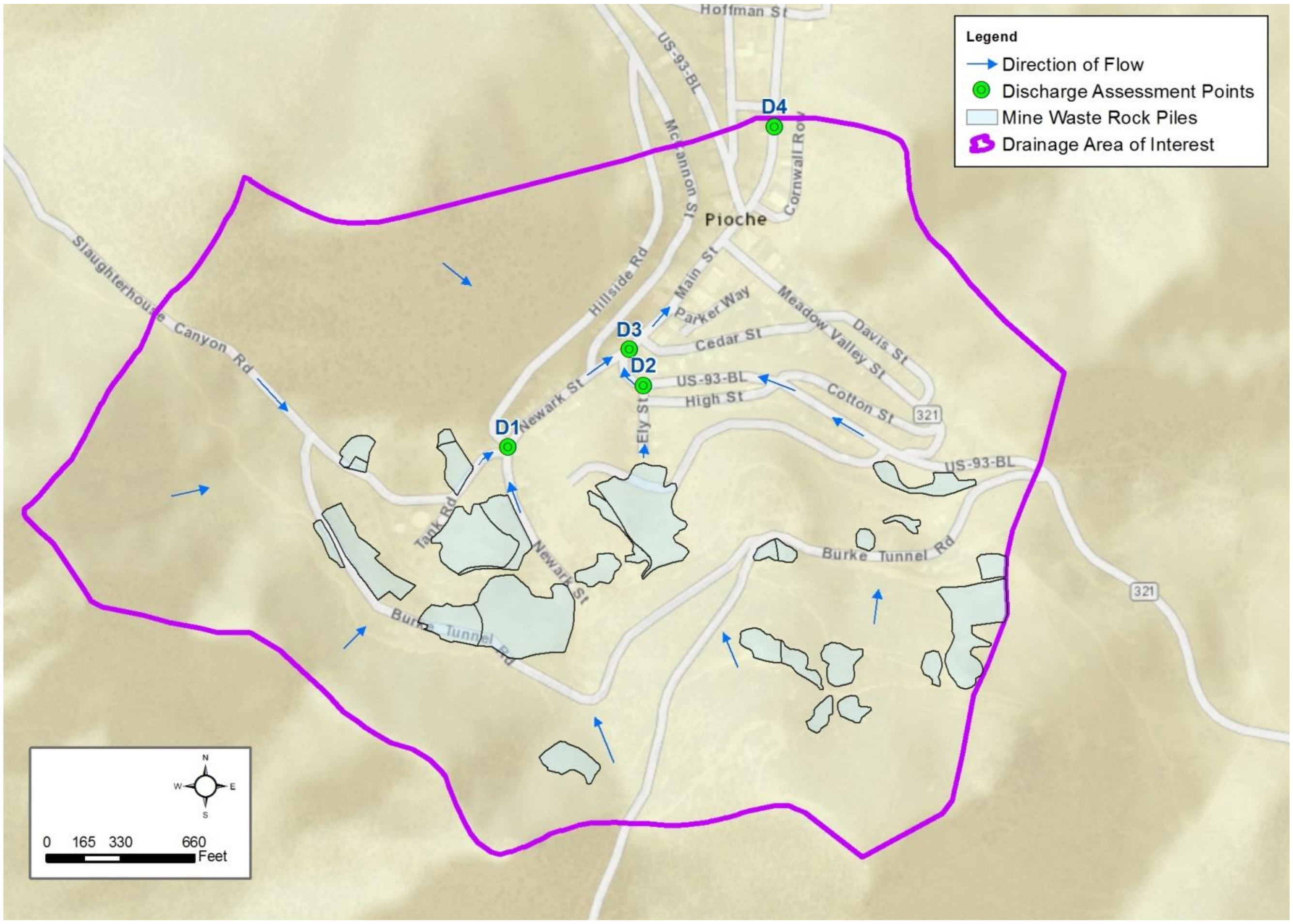

Figure 1. Stormwater Runoff Analysis Drainage Area

1.2 Purpose and Objectives

The purpose of this analysis is to develop a baseline model that can be used to support the OU-1 FS and subsequent remedial design/remedial action (RD/RA) activities. BC anticipates that the RD will consist of best management practices (BMPs) and stormwater runoff management facilities. The following objectives were achieved in the development of this runoff analysis:

- Estimate peak discharges for design storm events to size conveyance and bypass features.
- Estimate runoff volumes for design storm events to determine the storage capacity needed to detain and manage the runoff.
- Estimate safety factors to account for sediment bulking to be applied to peak discharges and storage volumes for proposed facilities.
- Compare the peak discharge and runoff volume estimates with similar results presented in the Stormwater CIP Study (SE, 2015).
- Evaluate design storm duration and intensity assumptions with respect to anecdotal information and historical rainfall data.

1.3 Document Organization

Section 2 describes the methodology used to meet the above objectives for the analysis, and Section 3 presents the results. Section 4 presents the methods and results for the comparison between this analysis and the analysis summarized in the SE CIP Study. Section 5 presents conclusions and recommendations for the design of BMPs and stormwater management facilities.

Section 2: Methodology

Modeling of the OU-1 baseline condition was divided into two tasks: 1) rainfall-runoff modeling to calculate peak design discharges and runoff volumes (Section 2.1); and 2) sediment bulking (i.e., loading factors were estimated using empirical relationships and conservative assumptions (Section 2.2).

2.1 Rainfall-Runoff Modeling

A rainfall-runoff model was developed to simulate design storms and calculate discharge hydrographs using event-based hydrologic methods developed by the U.S. Department of Agriculture National Resource Conservation Service (NRCS), formerly known as the Soil Conservation Service (SCS). These methods are collectively referred to as the *SCS method*, or the SCS-curve number method. Detailed guidance on SCS methods are provided in the National Engineering Handbook (NRCS, 1997).

Computations were performed using the Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) Version 4.0, which was developed by the U.S. Army Corps of Engineers (USACE, 2010). In general, HEC-HMS requires two types of input: 1) a meteorological model and 2) a basin model. The meteorological model represents climatic conditions (i.e., precipitation) occurring over a basin. The basin model represents the physical characteristics of a drainage basin. Subsections 2.1.1 and 2.1.2 describe the development of input data for the meteorological and basin models, respectively. Subsection 2.1.3 describes how these inputs are used to simulate design storm events to obtain runoff hydrographs that can be used to estimate peak discharges and runoff volumes.

2.1.1 Meteorological Model

The Precipitation-Frequency Atlas of the Western United States, developed by the National Oceanic and Atmospheric Administration (NOAA Atlas), is a standard reference for estimating rainfall depths for various durations and frequencies (Miller et al. 1973; Volume XIV specifically applies to Nevada). Point precipitation depths for 5-year to 1,000-year recurrence intervals, and durations from 5 minutes to 60 days can be obtained directly from NOAA's National Weather Service Hydrometeorological Design Studies Center[1] using geographic coordinates (latitude and longitude).

BC obtained precipitation-frequency data from the on-line NOAA Atlas for a point located roughly at the center of the upper Treasure Hill drainage, near an elevation of 6,340 feet. Table 1 provides a summary of the precipitation depths associated with a 24-hour event duration, which is the standard duration used for the SCS method (see Section 3.2 for addition discussion on event duration). A complete table of precipitation-depth-frequency data from the NOAA Atlas is provided in Attachment A.

Table 1. Precipitation Depths for 24-hour Storm Events

Precipitation Event (frequency and duration)	Precipitation Depth (inches)
5-year, 24-hour	2.07
10-year, 24-hour	2.43
25-year, 24-hour	2.93
50-year, 24-hour	3.33
100-year, 24-hour	3.74
200-year, 24-hour	4.17
500-year, 24-hour	4.76

Based on a latitude of 37.9249° N and a longitude of 114.4557° W, a point located on Treasure Hill above the Pioche downtown area

BC also obtained precipitation estimates for probable maximum precipitation (PMP), which is defined as "the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year, with no allowance made for long-time climatic trends" (WMO, 1986). Hydrometeorological Report No. 49 (HMR-49) developed by NOAA (1984) provides PMP estimates for storms in the Colorado River and Great Basin area. The General Storm PMP Maps indicate two storm patterns that are characteristic for eastern Nevada: 1) storms from the northwest with a 24-hour PMP depth of approximately 11.2 inches; and 2) and monsoonal storms from the southeast with a 24-hour PMP depth of approximately 8.3 inches.

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[1] http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nv

Table 2. Precipitation Depths for the 24-hour PMP

PMP Event	24-hour Precipitation Depth (inches)
Monsoonal Storms from the Southeast	8.3
General Storms from the Northwest	11.2

Precipitation depths were estimated by visual interpolation using 24-hour isohyetal maps provided in HMR-49 (NOAA 1984).

The precipitation depths obtained using the NOAA Atlas and HMR-49 are point values (i.e., the probability of the precipitation depth accumulating over the specified duration is associated with a single point within a storm). Because average precipitation intensity tends to decrease as the area of the storm increases, adjustment factors are typically used when applying precipitation depths over a drainage area. Because the OU-1 drainage area is relatively small (less than one square mile), areal reduction factors were considered to be negligible for the Treasure Hill analysis, and no adjustments were made to the point precipitation depths.

Hypothetical design storm events were created by temporally distributing the precipitation depths over the event duration (i.e., 24 hours) to form rainfall hyetographs. NRCS has developed four synthetic rainfall distributions for small watersheds (NRCS 1986; each is applicable to different regions of the United States). The *Type II* distribution is used for the State of Nevada, as this distribution applies to areas where extreme events are typically characterized as thunderstorms with a high peak intensity.

All four NRCS synthetic rainfall distributions are based on a standard 24-hour event duration. However, the distribution also reflects intensities associated with storms of lesser duration (NRCS, 1986). Longer duration events, or rainfall preceding the onset of a 24-hour storm event, can be accounted for by increasing the runoff curve number to reflect a higher antecedent runoff condition (ARC). However, it is difficult to relate this type of adjustment to a specific amount of antecedent rainfall or likelihood of occurrence; moreover, approaches to making such an adjustment are highly uncertain. For the OU-1 analysis, BC selected slightly conservative curve numbers and assumed a typical or “normal” ARC, and made no adjustments to the initial curve number (see Section 2.1.2.2 for additional discussion on curve number selection).

2.1.2 Basin Model

The SCS method uses a lumped-parameter approach to hydrologic modeling. Input data are developed for a set of sub-drainage areas, or subbasins. Each subbasin is assumed to have relatively uniform physical characteristics that can be represented by a single set of parameters. The spatial extent of the subbasins is represented by the delineated drainage area. Losses within the subbasin (interception, depression storage, infiltration, etc.) are represented by a curve number. And the rate at which excess precipitation (precipitation remaining after losses) is transformed to direct discharge at the subbasin outlet is represented by a synthetic unit hydrograph, which is scaled based on a calculated basin lag time. The methods used to develop the subbasins parameters are described in the following sections.

2.1.2.1 Subbasin Drainage Areas

The drainage basin corresponds to the area that drains to a point near the intersection of Main Street and Eugene Street, which is similar to one of the modeled subbasins in the SE CIP Study. The outlet discharge location serves as a point of comparison between the results from this study and the hydrologic calculations done for the CIP.

The drainage area includes three subbasins with discharge points located near the base of Treasure Hill, within the OU1 boundary, which were identified to be useful for design engineering purposes:

- D1: intersection of Tank Street and Newark Street
- D2: intersection of Ely Street and Main Street
- D3: intersection of Newark Street and Main Street

BC performed drainage basin and subbasin boundary delineations using an auto-delineation tool in AutoCAD based on regional topography derived from a 10-meter resolution digital elevation model (DEM) provided by the USGS National Digital Elevation dataset. The auto-delineated boundaries were then refined by hand based on detailed topographic mapping at 1- and 5-foot contour intervals, and field verification. Figure 2 shows the subbasin delineations and discharge points. Table 3 lists the A detailed map of the Site with the subbasins and discharge points is included in Attachment B.

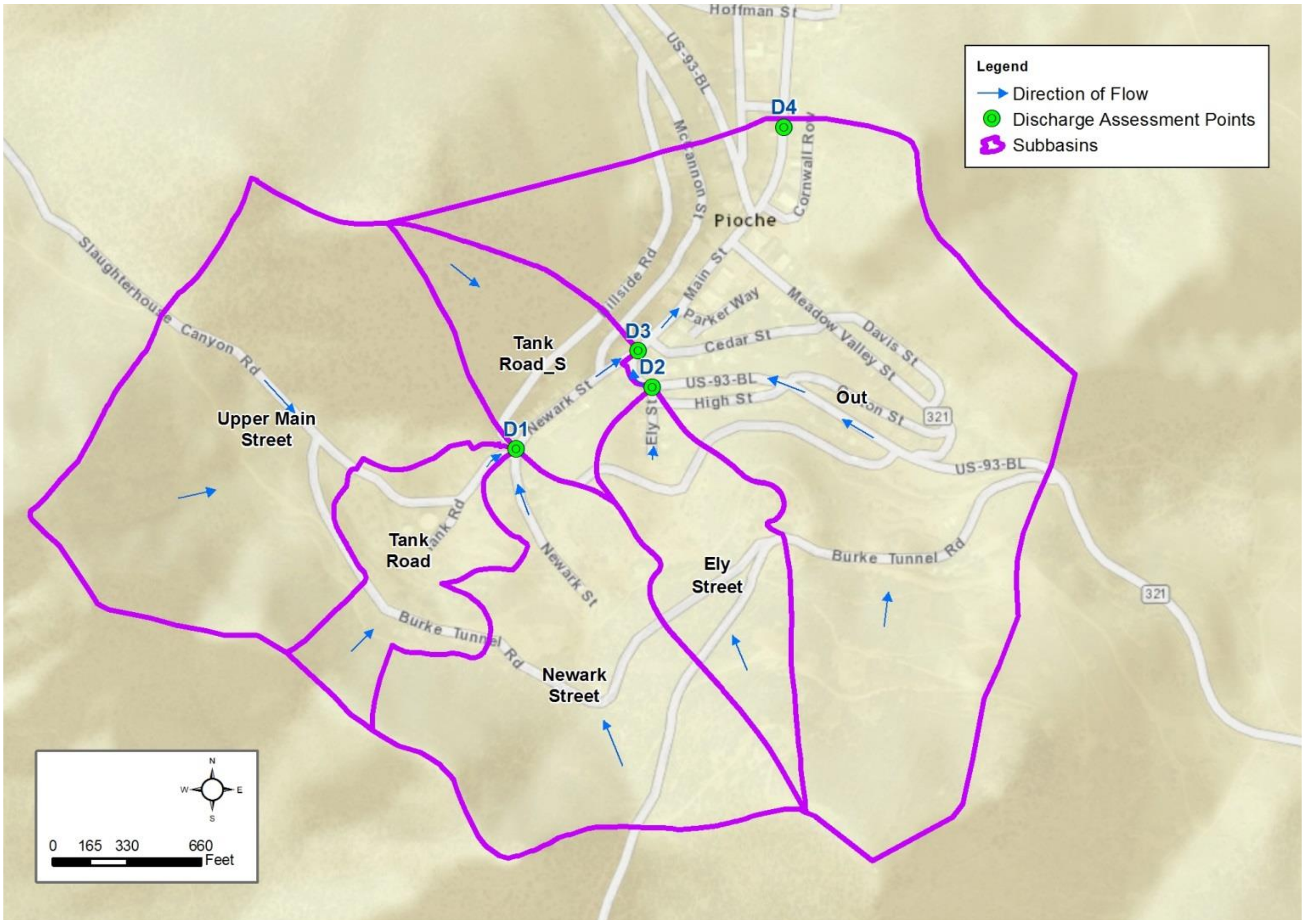

Figure2. Drainage subbasins for precipitation-runoff modeling

Table 1 Subbasin Areas

Subbasin ID	Area (Acres)	Area (Sq Mi)
Ely	17.7	0.028
Newark	40.6	0.063
Out (Discharge Point D4)	99.3	0.155
Tank	15.4	0.024
Tank_S	14.7	0.023
Upper	55.1	0.086
Total	**242.8**	**0.379**

2.1.2.2 Curve Numbers

The SCS method calculates runoff from a precipitation event as shown in the following equations from NRCS TR-55 (USDA 1986):

$$P_e = \frac{(P - I_a)^2}{(P - I_a) + S}$$

$$S = \frac{1000}{CN} - 10$$

$$I_a = \lambda S$$

where:

P_e = excess precipitation/runoff (inches)
P = precipitation (inches)
I_a = initial abstraction (inches)
S = retention storage (inches)
CN = curve number
λ = fraction of S used to estimate initial abstraction; typically assumed to be 0.2.

The initial abstraction value, I_a, is the amount of water lost before any runoff is generated, primarily due to interception storage, depression storage, and infiltration. The retention storage value, *S*, is the potential maximum retention within the watershed after runoff begins. Both I_a and S are functions of curve number, which is related to the vegetative cover and predominant soil type within the watershed.

BC conducted field investigations at the Site and observed: 1) various land cover types within the delineated drainage area: consisting mostly of desert shrub, pinyon-juniper trees, and dirt access roads (Figure 3); and 2) a natural desert landscape, paved areas, and waste rock piles (Figure 4). BC used NAIP aerial imagery (2013) to examine the extents of different land cover areas, which were then digitized manually using ArcGIS software (Figure 5). Observed land cover types were assigned to corresponding general land cover descriptions defined by the NRCS (1986) for arid and semiarid regions.

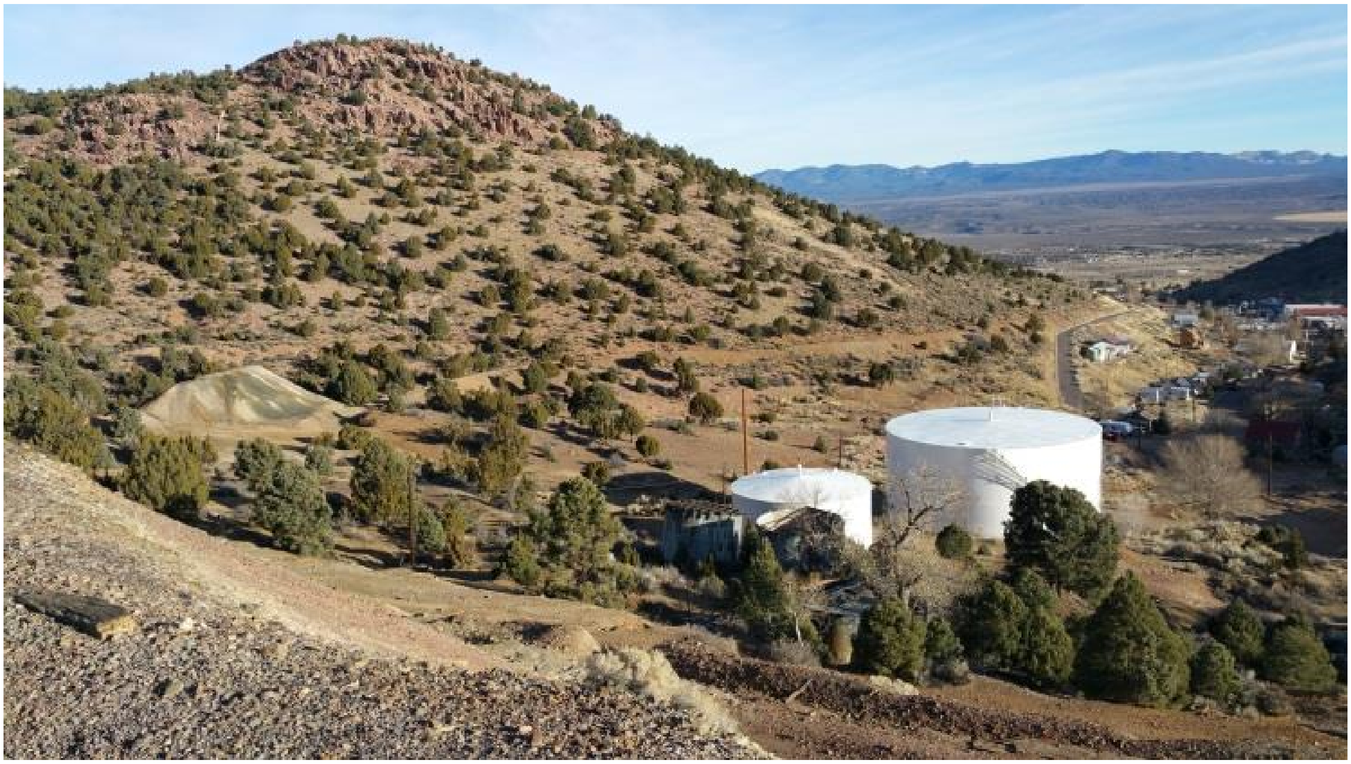

Figure 3. Vegetative cover in the upper portion of the OU-1 drainage basin (December 8, 2015)

Figure 4. Waste rock and bare soils in the upper OU-1 drainage basin (December 8, 2015)

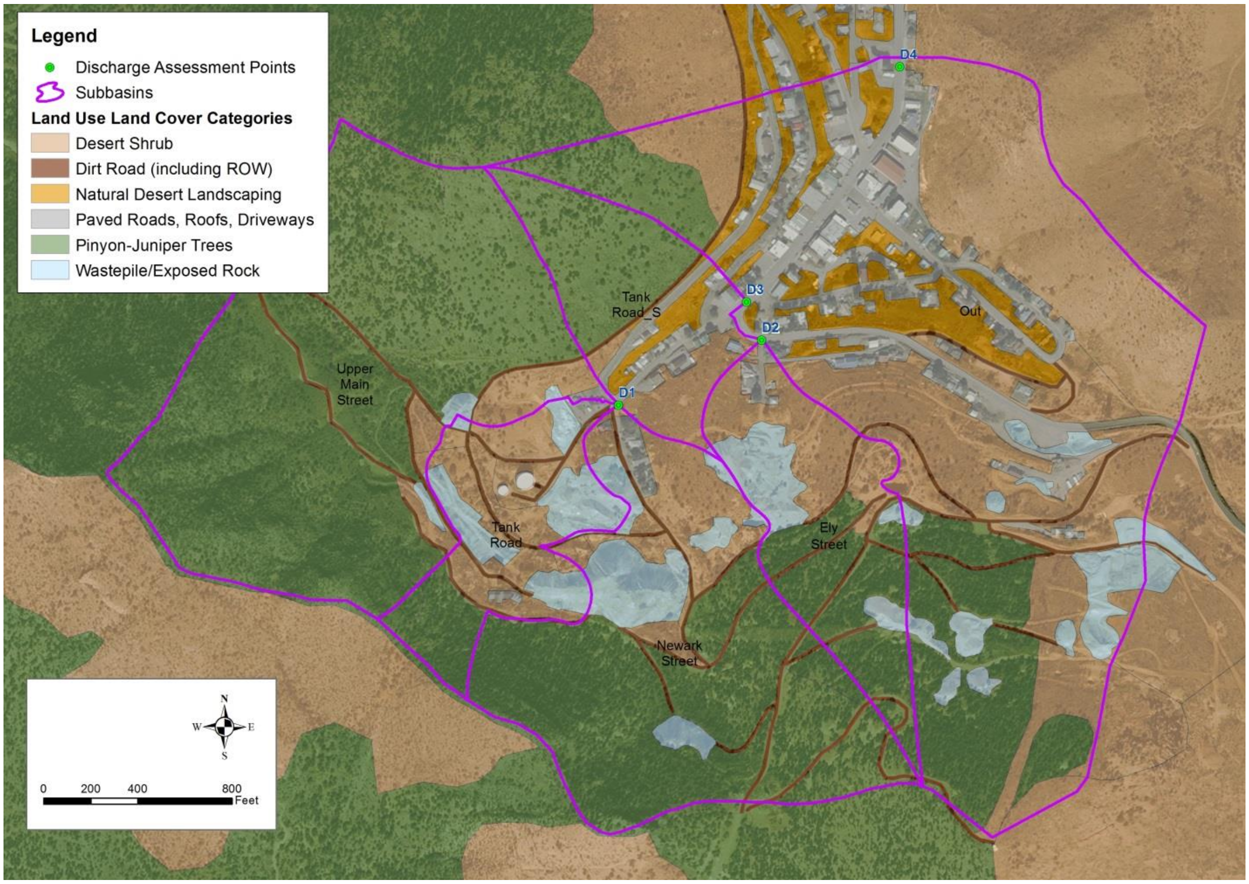

Figure 5. Mapped land use and vegetative cover for project site

Curve number selection is based on hydrologic soil groups (USDA, 1997), as follows:

- **Group A** soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 inches per hour).
- **Group B** soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 inches per hour).
- **Group C** soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 to 0.15 inches per hour).
- **Group D** soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 inches per hour).

For most areas of the country, NRCS has prepared detailed soil survey data—known as SSURGO data—with hydrologic soil group assigned to mapped soil units. BC obtained the SSURGO data for the Site and identified the soil units found within the drainage area (Table 4). Within the drainage area contains a mix of rock-outcrop complexes, gravelly clays, and extremely gravelly loam with slopes ranging from 15 to 75 percent. Despite this variability, all the OU-1 soils were classified as hydrologic soil group D.

Table 4. SURRGO Soil Data within Study Area

Map Unit Symbol	Map Unit Soil Type	Hydrologic Soil Group	Percent within Study Area, %
1492	Eaglepass- Rock outcrop complex, 15-75% slopes	D	14.90%
1514	Jarab-Blackcan association (cobbley loam, gravely clay)	D	4.50%
1706	Checklett extremely gravelly loam, 15-50 % slopes	D	80.60%

Information presented in this table is from the Meadow Valley Area, Nevada available soil data (NV713) from the NRCS SSURGO database.

Curve numbers for the existing conditions were selected from Table 2-2a of the TR-55 document (USDA 1986) for Type D soils with land cover types including various impervious surfaces and natural desert landscaping. Additional curve numbers were selected from Table 2-2d for arid and semiarid rangeland. Table 5 lists the curve numbers selected for each combination of land cover type, cover condition, and hydrologic soil group.

Table 5. Curve Numbers Selection for Drainage Area

Land Use Land Cover (LULC)	Cover Condition	Hydrologic Soil Group	Curve Number
Desert Shrub	Fair [a]	D	86
Pinyon-Juniper	Good [b]	D	71
Pinyon-Juniper	Fair	D	80
Dirt Road (including ROW)	Not Applicable	D	89
Natural Desert Landscaping	Not Applicable	D	88
Paved Parking Lots, Roofs, Driveways	Not Applicable	D	98
Paved Road with Open Ditch ROW	Not Applicable	D	93
Waste Rock Pile/ Gravel Road	Not Applicable	D	91
Desert Shrub	Fair	D	86

[a] *Fair: 30 to 70 percent ground cover*

[b] *Good: greater than 7 percent ground cover*

The land cover data were clipped by the subbasin areas using ArcGIS geospatial tools to determine the land use land cover classifications for each subbasin, and assigned a curve number based on the assignments in Table 5, above. Each curve number was then multiplied by its fraction of the total subbasin area to get the area-weighted curve number. Composite curve numbers for each subbasin are included in Table 6.

Table 6. Composite Curve Numbers and Initial Abstractions for Subbasins

Subbasin ID	CN	λ	S	I_a
Ely	81	0.2	2.4	0.5
Newark	77	0.2	3.0	0.6
Out (Discharge Point D4)	87	0.2	1.5	0.3
Tank	85	0.2	1.7	0.3
Tank_S	86	0.2	1.7	0.3
Upper	74	0.2	3.5	0.7

2.1.2.3 Basin Time of Concentration and Lag Time

The total runoff volume is equal to the volume of excess precipitation. Hydrologic models transform the volume of water from excess precipitation distributed over the basin to direct runoff at the basin outlet. This is often done using a unit hydrograph for the basin. If the basin is not gauged and no unit hydrograph can be developed, a synthetic unit hydrograph can be created based on basin characteristics. NRCS developed a synthetic unit hydrograph known as the SCS Dimensionless Unit Hydrograph (USDA, 1972c). The SCS Dimensionless Unit Hydrograph is a parametric unit hydrograph model.

The ordinates of the unit hydrograph are calculated from two parameters representing the basin response: basin area (*A*) and the basin lag time (*L*). The basin lag time is defined as the time difference between the center of mass of the excess rainfall and the peak of the unit hydrograph. The lag time for a basin can be estimated as a fraction of the time of concentration, which is the travel time along the longest flow path from the distal edge of the drainage basin to the outlet. The lag time is typically estimated as follows:

$$L = 0.6(T_c)$$

where:

L = lag time of basin

T_c = time of concentration of longest flow path within basin

The time of concentration was determined by standard method presented in the NRCS TR-55 document, referred to as the velocity method (USDA 1986). The velocity method is based on the assumption that the time of concentration is the sum of travel times for each segment of the longest flow path within the basin, segmented based on the flow type; sheet flow, shallow concentrated flow, and open channel flow.

$$T_c = T_{t1} + T_{t2} + T_{t3} + \ ...T_n$$

where:

T_c = time of concentration, h
T_{tn} = travel time of a segment n, h
n = number of segments comprising the total hydraulic length

Table 7 lists the calculated the estimated time of concentration and lag time for each subbasin.

Table 7. Time of Concentration and Lag Times for Subbasins

Subbasin	Tc (min)	Lag Time (min)
Ely	10.50	6.3
Newark	8.10	4.9
Out (Discharge Point D4)	19.3	11.6
Tank	7.00	4.2
Tank_S	8.90	5.3
Upper	12.30	7.4

The peak discharge of the unit hydrograph (q_p) and the time-of-peak (T_p) are related to the basin area and the basin lag time by the following equations from USDA (1972c):

$$q_p = \frac{CAQ}{T_p}$$

$$T_p = \frac{\Delta D}{2} + L$$

where:

q_p = peak discharge of the unit hydrograph
C = a conversion constant = 484 for English units
A = basin area (square miles)
Q = total volume of runoff/excess precipitation (1 inch)
T_p = time to peak (hours)
L = basin lag time (hours)
ΔD = duration of excess precipitation (hours).

2.1.2.4 Baseline Model Schematic

A HEC-HMS Model schematic is presented below in Figure 5, showing the subbasins, drainage connections, and additional computational nodes (junctions).

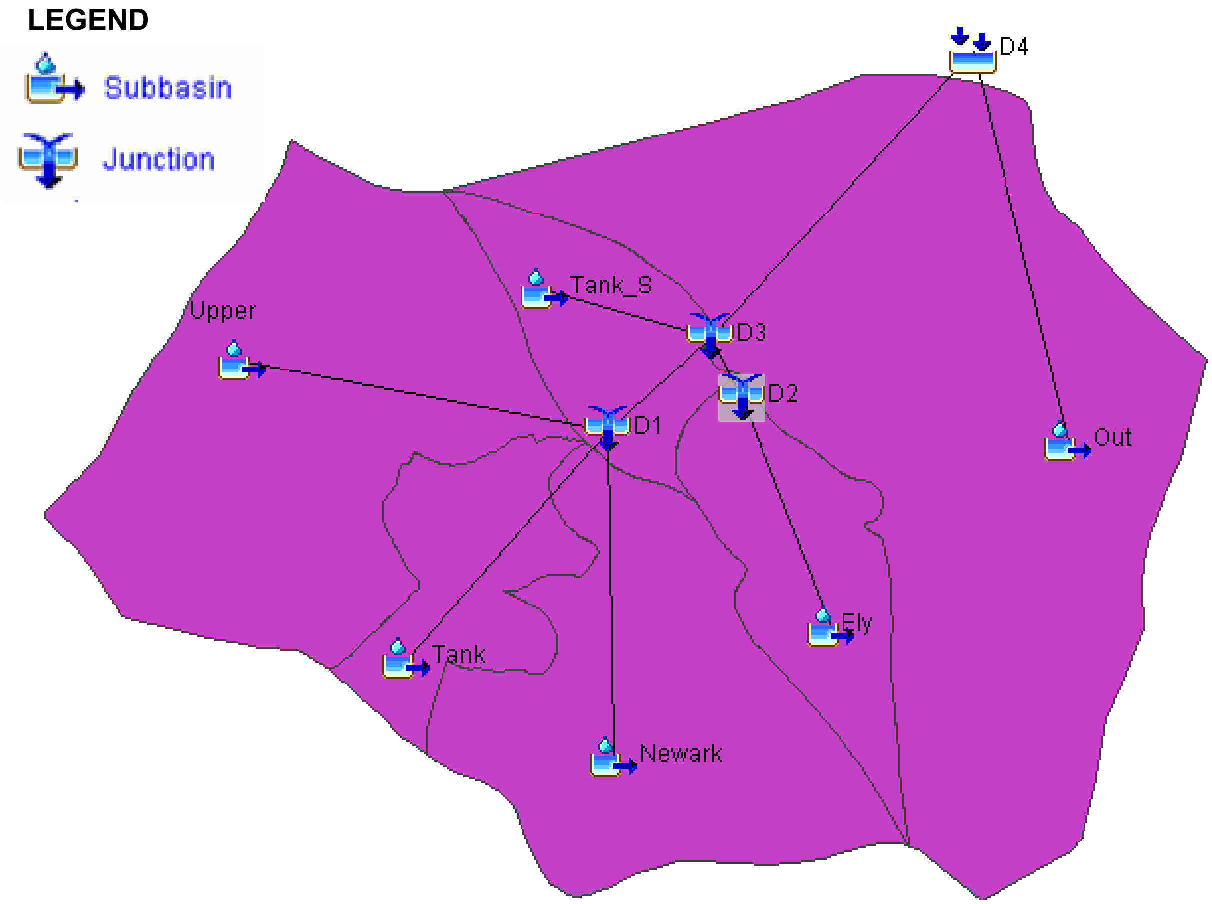

Figure 5. Baseline Model Schematic for the OU-1 Drainage Basin

2.1.3 Event Simulation

The meteorological model and basin model are combined under a control specification to complete the event simulation. The control defines the event duration and time interval of the simulation. For the OU-1 analysis, the control was set for a 24-hour time duration, and a 5-min time interval.

2.2 Sediment Bulking

Erosion and transport of soil, sediment, and debris during significant precipitation events can substantially increase runoff volumes, especially in arid regions with sparse vegetation and exposed sediments on steep slopes (as seen in Figure 6). Therefore, BC estimated potential increases in runoff volumes, referred to as sediment bulking.

Figure 6. Bare earth and sloped surfaces on OU-1 Site (December 8, 2015)

The United States Geological Survey (USGS) has published two studies on sediment bulking: one by Scott and Williams (1978) and one by Gartner, Cannon and Helsel (2009). Each study developed empirical equations based on data collected in the Transverse Ranges of southern California, which is an arid region with climate, soils and vegetation that are similar to that of the OU-1 area. BC used a total of five empirical equations from the USGS studies to estimate sediment bulking volumes. These equations were developed using regression analyses that incorporate multiple physical parameters contributing to sediment availability, mobilization and transport (e.g., soil type, basin geometry, event rainfall and wild fire history). BC developed input parameters for each of the equations based on geospatial data, observations, and typical conditions for the region. In cases where an input parameter is unknown or subject to substantial uncertainty, BC performed sensitivity testing to select reasonable and conservative values.

After comparing the results from all five equations, BC selected "Equation 1" from Gartner, Cannon and Helsel (2009) as the best option for sediment bulking calculations (this equation produced results that were more conservative but reasonable based on best professional judgment). In addition, the following input parameters for Equation 1 are easily estimated or can be assumed with reasonable certainty.

$$\log(V) = 2.2 + 0.7\log(R) + 0.1\sqrt{B} + 0.3LE + 0.5\log(A) + 0.02S - 2.1RR + 0.5^2 * 0.5$$

where:

$V = sediment\ yield\ (m^3)$
$R = peak\ 1\ hour\ rainfall\ depth\ (mm)$
$B = Burned\ area\ in\ last\ fire\ (km^2)$
$LE = Lingering\ Effect = e^{-0.5t};\quad t = years\ since\ last\ fire$
$A = basin\ area\ (km^2)$
$S = average\ basin\ slope\ (\%)$

$$RR = Relief\ Ratio$$

The sensitivity analysis for Equation 1 included two input parameters: B (burned area) and LE (lingering effect). The analysis indicated that sediment yield was relatively insensitive to B. Therefore the final results are based on conservatively assuming that 100% of the area burned during the last fire. Sediment yield did exhibit sensitivity to LE, and a reasonable value of 0.01 was selected (coordinating with the last fire occurring ten years prior). Detailed calculations can be found in Attachment C.

Section 3: Results and Discussion

As described in Section 2.1, rainfall-runoff modeling was performed using standard SCS methods and computed using HEC-HMS software. The hydrologic simulations produced discharge hydrographs from hypothetical design storms that correspond with estimated recurrence intervals (e.g., 100 years). These recurrence intervals are most appropriately conceptualized in terms of risk, or the chance of an event occurring in any one year. For example, there is a 1-percent chance that a 100-year event or greater will occur in any given year (1/100 = 0.01 = 1 percent). A key assumption in the analysis is that precipitation frequency is directly related to flow frequency. Calculated peak discharges in cubic feet per second (cfs) and runoff volumes in acre-feet (ac-ft) for a range of recurrence intervals are presented in Tables 8 and 9, respectively. Attachment D provides detailed HEC-HMS model output tables for each scenario.

Table 8. Summary of Peak Discharges

Discharge Node	Location	Total Drainage Area		Peak Discharge (cubic feet per second)						
		(acres)	(mi^2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	110.7	0.173	64	95	144	185	230	278	346
D2	Ely Street/Main Street intersection	17.9	0.028	15	21	30	37	45	53	65
D3	Newark Street/Main Street intersection	143	0.224	96	139	205	261	320	384	474
D4	South of Main Street/Cornwall Row intersection	243	0.379	183	255	361	451	546	647	789

Table 9. Summary of Runoff Volumes

Discharge Node	Location	Total Drainage Area		Runoff Volume (acre-feet)						
		(acres)	(mi^2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	110.7	0.173	4.5	6.4	9.4	12.0	14.8	17.8	22.2
D2	Ely Street/Main Street intersection	17.9	0.028	1.0	1.3	1.9	2.3	2.8	3.4	4.1
D3	Newark Street/Main Street intersection	143	0.224	6.6	9.2	13.2	16.7	20.4	24.5	30.3
D4	South of Main Street/Cornwall Row intersection	243	0.379	14.5	19.5	27.0	33.4	40.2	47.5	57.8

The results of the sediment bulking calculations are provided in Table 10; values are presented in the table represent the total transported sediment, or sediment yield. For design purposes, the volume of sediment transported can be added directly to the runoff volumes to obtain a total volume of sediment-laden runoff that would need to be managed for any particular design storm event.

Table 10. Summary of Sediment Bulking Volumes

Discharge Node	Location	Total Drainage Area		Sediment Volume (acre-feet)						
		(acres)	(mi^2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	110.7	0.173	2.1	2.3	2.6	2.9	3.1	3.4	3.7
D2	Ely Street/Main Street intersection	17.9	0.028	0.5	0.5	0.6	0.6	0.7	0.7	0.8
D3	Newark Street/Main Street intersection	143.4	0.224	2.9	3.3	3.7	4.1	4.4	4.8	5.2
D4	South of Main Street/Cornwall Row intersection	243	0.379	4.7	5.2	6.0	6.6	7.1	7.7	8.4

3.1 Comparison with Regional Statistics

Peak discharge estimates can vary greatly, especially for small drainages with steep slopes where intense rainfall can yield extreme peaks on runoff hydrographs. Therefore, BC performed ancillary calculations to check the reasonableness of the results. The first of two checks is based on regional regression equations developed by USGS (1998) were used to calculate peak discharges for comparison. The Site is located in Nevada Region 6 which uses the following general equation:

$$Q_T = A * \ (Area)^a \left(\frac{Elevation}{1000}\right)^{-b}$$

where:

Q_T = discharge for recurrence interval T, for 5 to 100 years, in cfs
Area = drainage area in square miles
Elevation = mean basin elevation in feet above sea level
A = regression equation coefficient
a,b = regression equation exponents

Peak discharges for Region 6 of Nevada are summarized in Table 11. Regression questions and supporting calculations are included in Attachment E.

Table 11. Discharge-frequency at D4 based on USGS Regional Regression Equations

Peak Discharge by duration in years	Peak Discharge, cfs	24-hr Peak Discharge, cfs
5-YR	4.4	183
10-YR	16.8	255
25-YR	36.3	361
50-YR	58.9	451
100-YR	174.3	546

The discharge estimates obtained using the USGS regional regression equations are less than the peak design storm discharges. This is to be expected given that the USGS regression equations were developed using historical data from largely undeveloped watersheds that are generally larger and not as steep as the OU-1 drainage area (the USGS estimate provides a lower bound to the discharge frequency estimates).

Conversely, an upper bound can be obtained from a regional envelope curve. Crippen and Bue (1997) developed regional envelope curves based on extreme historical events to understand the upper limit of possibility for peak discharges for a particular drainage area. The envelope curves were developed based stream gauge data from 883 sites throughout the Unites States, grouped by regions. The envelope for Region 16 in Nevada shows a maximum flow for a drainage basin of 0.38 square miles to be approximately 3,500 cfs (see figure in Attachment F). This result indicates that small watersheds can have extremely high runoff potential, which suggests that while the simulated peak discharges for the drainage areas appear high, they are reasonable and should not be considered to be overly conservative.

3.2 Comparison with Observed Events

BC reviewed precipitation records obtained from the NOAA National Climate Data Center (NCDC) for NOAA Cooperative Rain Gage Station No. 266252, located in downtown Pioche. Data at this gauge are recorded in 15-minute time intervals. Two recent rainfall events were noted and compared with design storm frequency and intensity. The first event is a long-duration, low-intensity event that occurred in December 2010. The second event is a short-duration, high-intensity event that occurred in August 2013. A discussion of each event is presented below.

3.2.1 December 2010 Long-duration Event

In December 2010, 6.7 inches of rainfall fell over a 5-day period from December 17 to December 22. Despite the substantial cumulative total, the maximum rainfall intensity during the event was only about 0.4 inches per hour. Comparing this with the NOAA Atlas data in Attachment A, BC found that this event is similar to a 500-year recurrence. Despite the extreme nature of the rainfall, such an event is not likely to produce extreme discharges from OU-1 because the drainage basin is small and runoff would reach the outlet within minutes. Figure 7 below shows how a 100-year, 24-hour design storm compares with the December 2010 event in terms of rainfall intensity (inches per hour).

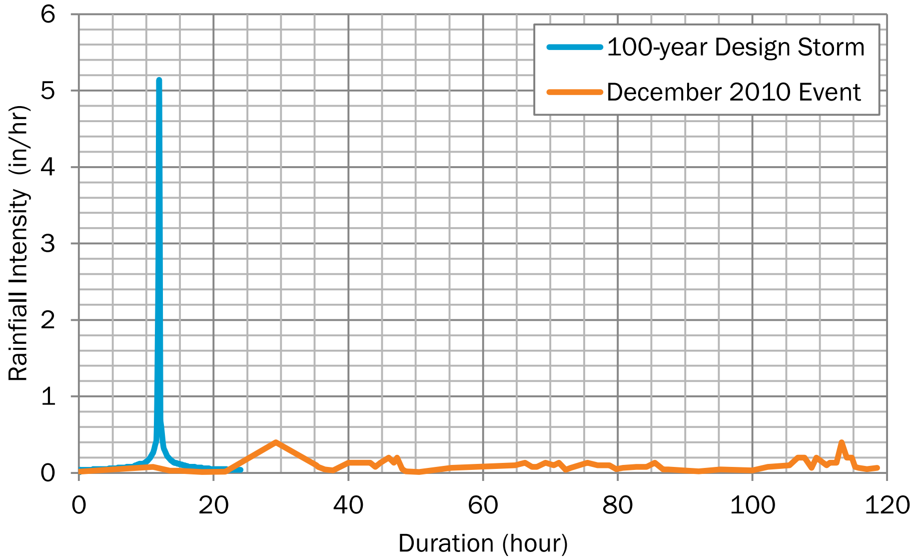

Figure 7. Comparison between December 2010 event and a 100-year design storm

3.2.2 August 2013 High-intensity Event

In August 2013, the Town of Pioche experienced substantial stormwater runoff and sedimentation along streets and low-lying areas of town. Photo documentation of the August 2013 event was included in the SE CIP Study (Sunrise 2015). Data recorded at 15-minute intervals indicate that a total of 3.1 inches fell within 24 hours; however 2.9 inches of that fell within an intense 90-minute period. Comparing this with the NOAA Atlas data in Attachment A, the 24 hour rainfall was somewhere between a 25-year and 50-year event. The 2.9 inch total is closer to a 500-year event. Figure 8 shows how the August 2013 event compares with a 100-year design storm in terms of rainfall intensity (inches per hour) based on the available data.

BC used the 24-hour rainfall depths and distribution from the recorded data to run a HEC-HMS simulation of the August 2013 event, which produced a peak discharge of 439 cfs at Discharge Point D4 and a runoff volume of 29.8 ac-ft. These results correspond to a 50-year, 24-hour design storm event. However, it should be noted that the peak intensity of the observed rainfall is somewhat limited by the 15-minute recording increment used by the rain gauge. Nevertheless, Figure 8 shows how the August 2013 event compares with a 100-year design storm in terms of rainfall intensity (inches per hour) based on the available data.

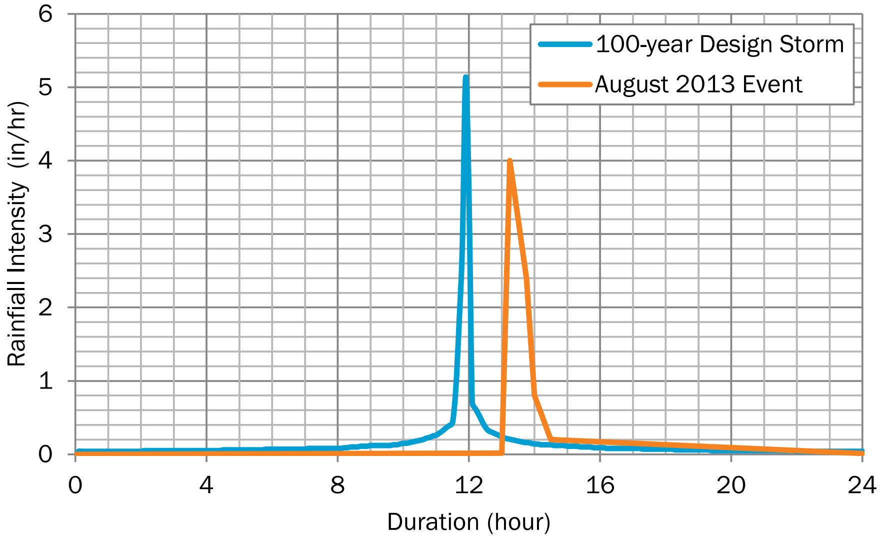

Figure 8. Comparison between August 2013 event and a 100-year design storm

3.3 Comparison with Sunrise Engineering Analysis

As part of the CIP Study, SE performed precipitation-runoff modeling to help size stormwater management facilities. *Subbasin 88b* in the CIP Study was used by BC for the runoff analysis presented in this TM. Table 12 compares the SE results with the BC results at Discharge Point D4.

Table 12. CIP Study Results Comparison for 100-year, 24-hour Design Storm

Modeling Study	Precipitation Depth (inches)	Basin Area (sq. mi)	Peak Discharge (cfs)	Volume (ac-ft)
CIP Study by SE (2015)	6.46[a]	0.379	62	93
BC Runoff Analysis (2016)	3.74	0.379	546	40

a. *SE added a depth of 2.8 in of rainfall to the 100-year 24-hr depth (3.66 in) to simulate a rain-on-snow event*

The most significant difference between the SE and BC approaches is the assumed temporal distribution of precipitation. BC used an SCS Type II storm with an intense central peak, while the SE model used a uniform distribution (Figure 9).

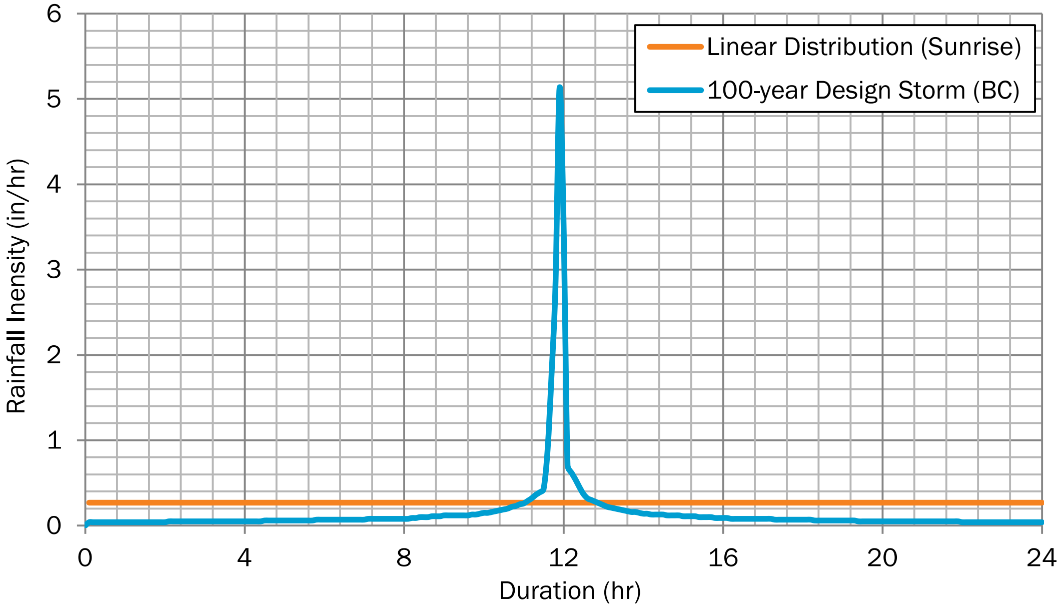

Figure 9. Comparison of the precipitation distributions used by Sunrise and BC

Table 13 provides a summary of the known differences between the Sunrise and BC approaches.

Table 13. Key Differences for Input Parameters and Assumptions Between the BC and Sunrise Model Analyses

Parameter/Assumption	Sunrise Model	BC Model	Comments
Number of subbasins	1	6	BC model was split into 6 subbasins versus the Sunrise model which included one basin ("88b")
Rainfall distribution for 100-yr, 24hr event	Linear	SCS Type II	SCS Type II is a widely accepted distribution for runoff modeling (NRCS 1986)
Maximum Intensity (in/hr)	0.27	5.13	The SCS Type II distribution has a high intensity at the center of the storm, characteristic of thunderstorms, in contrast to a linear distribution which has the same intensity throughout the storm duration.
Rainfall depth for 100-yr, 24hr event (in)	3.66	3.74	The NOAA Point Precipitation data was selected from different locations. The BC location was selected further up the hillside (6340 ft elevation) from the Sunrise location in the downtown area (6008 ft), because rainfall is expected to be greater at the higher elevation and is more characteristic of the project site.
Rain on snow event adjustment	2.8 in SWE	none	Sunrise added a depth of 2.8 in of rainfall to the 100-year 24-hr depth (3.66 in) to simulate a rain-on-snow event, assuming this would be the worst-case scenario. BC did not adjust for snowmelt, assuming that an intense storm event is likely to occur in spring or summer seasons when the chance of a significant snow pack is minimal.
Average CN	83	82	Slight differences in land use land cover mapping resulted in a difference in the average CN between the model subbasin(s).
Basin lag time (min)	10.0	6.6	The average lag time presented is based on several flow paths which capture the range of flow path time of concentrations (long and short), versus the sunrise model which is a lumped model with a less refined time of concentration.

Section 4: Summary of Runoff Analysis

The majority of the Treasure Hill area drains into the town of Pioche along Newark and Main Streets, which can lead to runoff and sedimentation problems during large rainfall events. The hydrologic model of the drainage basin was developed by BC using standard SCS methods to calculate peak discharges and runoff volumes, which can be used to develop a remedial design for BMPs and stormwater management facilities. BC also evaluated the potential for mobilized sediment to contribute to stormwater management issues by calculating bulking volumes. Tabulated results have been presented for design storms ranging from 5- to 500-year recurrences. BC also preformed several quantitative comparisons to assess the reasonableness of the results and provide addition insights on the methods used. Based on these comparisons, BC found that:

- The SCS method used by BC produced peak discharges that are reasonable when compared with other methods that provide plausible lower and upper bounds.
- The 5-day event that occurred in Pioche in December 2010 was a long-duration, low-intensity event that could be viewed as having roughly a 500-year recurrence. However, the peak discharges were probably inconsequential because of the consistently low rainfall intensity.
- The precipitation event that occurred in Pioche in August 2013 was a short-duration, high-intensity event that could be viewed as having roughly a 500-year recurrence. However, due to a lack of detailed rainfall data, BC could not correlate the peak discharge and runoff volumes with a 500-year event.
- The modeling completed by SE for the CIP Study produced 100-year peak discharges that are much less than those calculated by BC, primarily due to very different assumptions in rainfall distribution.
- The modeling completed by SE for the CIP Study produced 100-year runoff volumes that are significantly greater than those calculated by BC, primarily due to the Sunrise's assumption that an additional 2.8 inches of water is available as rainfall to account for potential warm rain on snow runoff event.

The modeling results presented herein represent a baseline condition and can be used to inform decisions regarding possible design criteria for BMPs and stormwater management facilities. Peak discharges can be used to size bypass diversions and or conveyance structures, and runoff volumes and hydrographs can be used to size detention ponds or storage for runoff/sediment management. The results presented in this TM were provided for a larger drainage basin area (subbasin 88b, as described in the SE CIP Study) than the OU-1 boundary. For remedial design purposes, the runoff rates and volumes, and sediment bulking calculation results described above, are reproduced in Tables 14 through 16 for only the three discharge points and subbasins within the OU-1 boundary (results are based on SCS Type II rainfall distribution with a 5-minute interval).

Table 14a. Summary of Peak Design Discharges [1]

Discharge ID	Location	Drainage Area		Peak 24-Hour Discharge (cubic feet per second)						
		(acres)	(mi2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	111	0.17	64	95	144	185	**230**	278	346
D2	Ely Street/Main Street intersection	18	0.03	15	21	30	37	**45**	53	65
D3	Newark Street/Main Street intersection	143	0.22	96	139	205	261	**320**	384	474

Table 14b. Summary of Peak Design Discharges [1]

Discharge ID	Location	Drainage Area		Peak 24-Hour Discharge (gallon per minute)						
		(acres)	(mi2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	111	0.17	28,546	42,729	64,452	83,124	103,097	124,775	155,476
D2	Ely Street/Main Street intersection	18	0.03	6,553	9,246	13,241	16,607	20,153	23,923	29,219
D3	Newark Street/Main Street intersection	143	0.22	43,133	62,567	91,966	116,966	143,582	172,352	212,836

Table 15a. Summary of Runoff Volumes[1]

Discharge ID	Location	Drainage Area		Runoff Volume (acre-feet)						
		(acres)	(mi2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	110.72	0.173	4.5	6.4	9.4	12.0	**14.8**	17.8	22.2
D2	Ely Street/Main Street intersection	17.92	0.028	1.0	1.3	1.9	2.3	**2.8**	3.4	4.1
D3	Newark Street/Main Street intersection	143.36	0.224	6.6	9.2	13.2	16.7	**20.4**	24.5	30.3

Table 15b. Summary of Runoff Volumes[1]

Discharge ID	Location	Drainage Area		Runoff Volume (million gallons)						
		(acres)	(mi2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	110.72	0.173	1.47	2.09	3.06	3.91	4.82	5.80	7.23
D2	Ely Street/Main Street intersection	17.92	0.028	0.33	0.42	0.62	0.75	0.91	1.11	1.34
D3	Newark Street/Main Street intersection	143.36	0.224	2.15	3.00	4.30	5.44	6.65	7.98	9.87

Table 16. Summary of Sediment Bulking Volumes

Discharge Node	Location	Total Drainage Area		Sediment Volume (acre-feet)						
		(acres)	(mi^2)	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
D1	Tank Street/Newark Street intersection	110.7	0.173	2.1	2.3	2.6	2.9	3.1	3.4	3.7
D2	Ely Street/Main Street intersection	17.9	0.028	0.5	0.5	0.6	0.6	0.7	0.7	0.8
D3	Newark Street/Main Street intersection	143.4	0.224	2.9	3.3	3.7	4.1	4.4	4.8	5.2

Section 5: References

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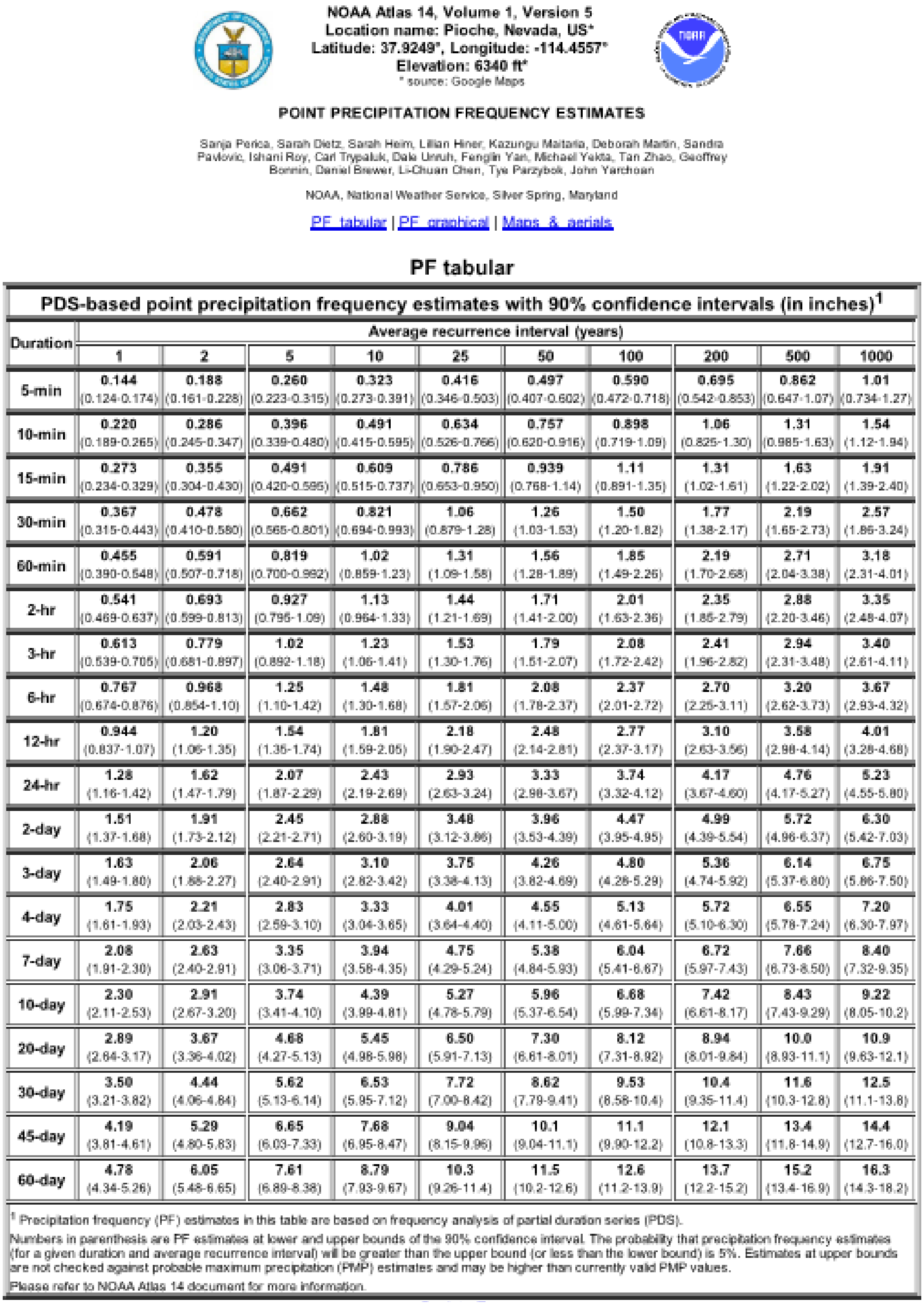
Attachment A: NOAA Point Precipitation Frequency Data



NOAA Atlas 14, Volume 1, Version 5
Location name: Pioche, Nevada, US*
Latitude: 37.9249°, Longitude: -114.4557°
Elevation: 6340 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

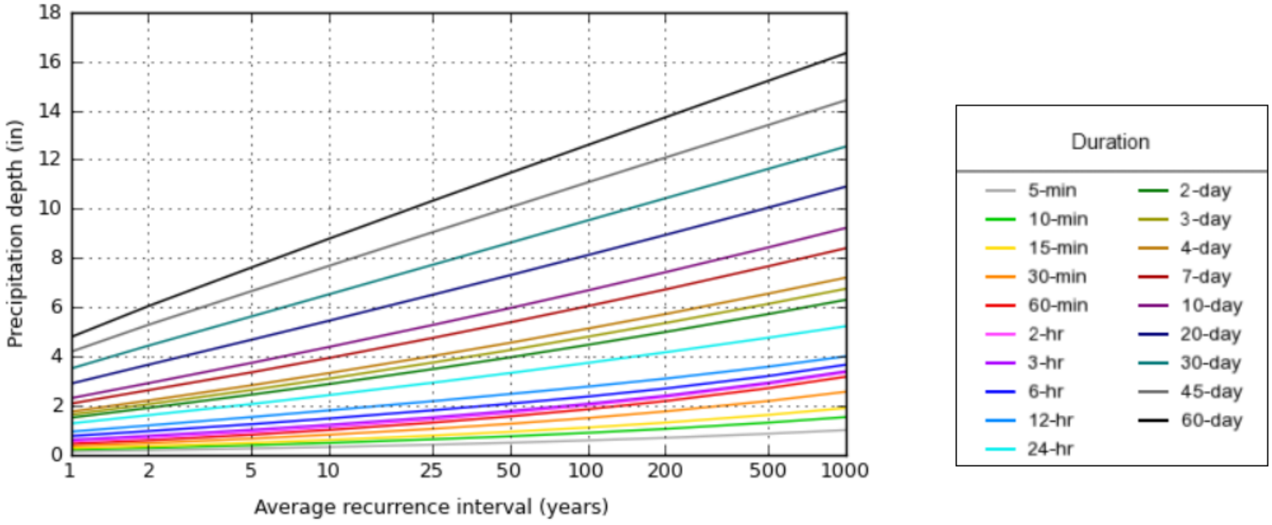
PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

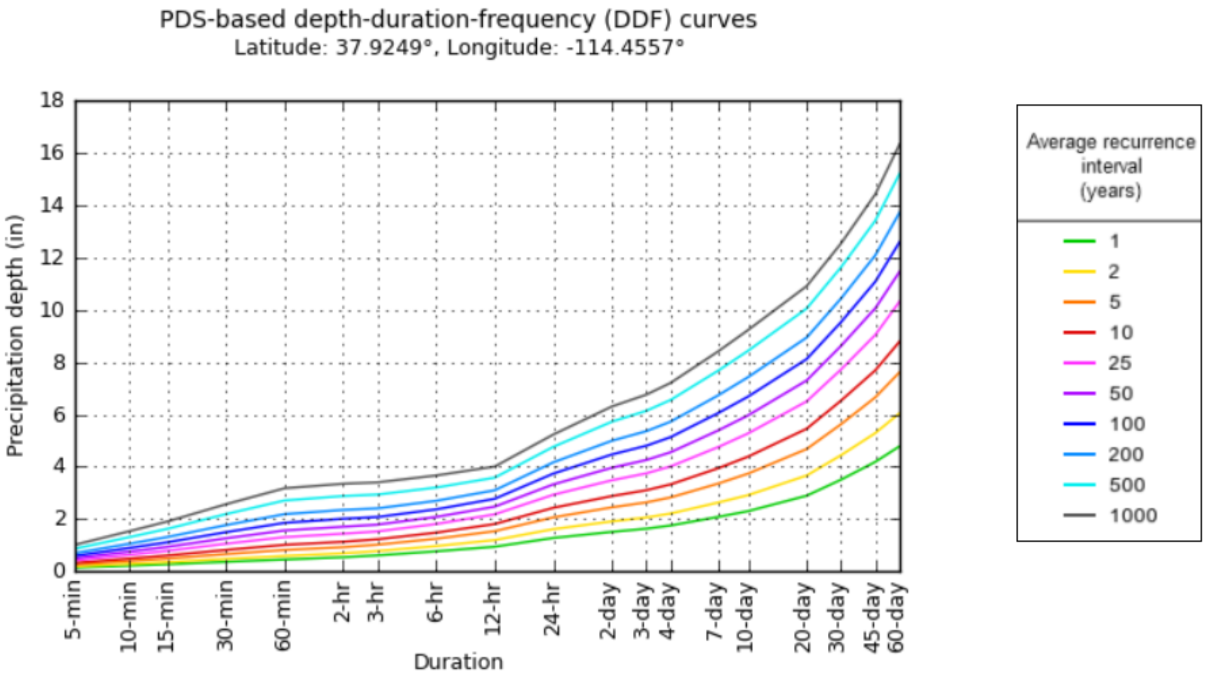
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.144 (0.124-0.174)	0.188 (0.161-0.228)	0.260 (0.223-0.315)	0.323 (0.273-0.391)	0.416 (0.346-0.503)	0.497 (0.407-0.602)	0.590 (0.472-0.718)	0.695 (0.542-0.853)	0.862 (0.647-1.07)	1.01 (0.734-1.27)
10-min	0.220 (0.189-0.265)	0.286 (0.245-0.347)	0.396 (0.339-0.480)	0.491 (0.415-0.595)	0.634 (0.526-0.766)	0.757 (0.620-0.916)	0.898 (0.719-1.09)	1.06 (0.825-1.30)	1.31 (0.985-1.63)	1.54 (1.12-1.94)
15-min	0.273 (0.234-0.329)	0.355 (0.304-0.430)	0.491 (0.420-0.595)	0.609 (0.515-0.737)	0.786 (0.653-0.950)	0.939 (0.768-1.14)	1.11 (0.891-1.35)	1.31 (1.02-1.61)	1.63 (1.22-2.02)	1.91 (1.39-2.40)
30-min	0.367 (0.315-0.443)	0.478 (0.410-0.580)	0.662 (0.565-0.801)	0.821 (0.694-0.993)	1.06 (0.879-1.28)	1.26 (1.03-1.53)	1.50 (1.20-1.82)	1.77 (1.38-2.17)	2.19 (1.65-2.73)	2.57 (1.86-3.24)
60-min	0.455 (0.390-0.548)	0.591 (0.507-0.718)	0.819 (0.700-0.992)	1.02 (0.859-1.23)	1.31 (1.09-1.58)	1.56 (1.28-1.89)	1.85 (1.49-2.26)	2.19 (1.70-2.68)	2.71 (2.04-3.38)	3.18 (2.31-4.01)
2-hr	0.541 (0.469-0.637)	0.693 (0.599-0.813)	0.927 (0.795-1.09)	1.13 (0.964-1.33)	1.44 (1.21-1.69)	1.71 (1.41-2.00)	2.01 (1.63-2.36)	2.35 (1.85-2.79)	2.88 (2.20-3.46)	3.35 (2.48-4.07)
3-hr	0.613 (0.539-0.705)	0.779 (0.681-0.897)	1.02 (0.892-1.18)	1.23 (1.06-1.41)	1.53 (1.30-1.76)	1.79 (1.51-2.07)	2.08 (1.72-2.42)	2.41 (1.96-2.82)	2.94 (2.31-3.48)	3.40 (2.61-4.11)
6-hr	0.767 (0.674-0.876)	0.968 (0.854-1.10)	1.25 (1.10-1.42)	1.48 (1.30-1.68)	1.81 (1.57-2.06)	2.08 (1.78-2.37)	2.37 (2.01-2.72)	2.70 (2.25-3.11)	3.20 (2.62-3.73)	3.67 (2.93-4.32)
12-hr	0.944 (0.837-1.07)	1.20 (1.06-1.35)	1.54 (1.35-1.74)	1.81 (1.59-2.05)	2.18 (1.90-2.47)	2.48 (2.14-2.81)	2.77 (2.37-3.17)	3.10 (2.63-3.56)	3.58 (2.98-4.14)	4.01 (3.28-4.68)
24-hr	1.28 (1.16-1.42)	1.62 (1.47-1.79)	2.07 (1.87-2.29)	2.43 (2.19-2.69)	2.93 (2.63-3.24)	3.33 (2.98-3.67)	3.74 (3.32-4.12)	4.17 (3.67-4.60)	4.76 (4.17-5.27)	5.23 (4.55-5.80)
2-day	1.51 (1.37-1.68)	1.91 (1.73-2.12)	2.45 (2.21-2.71)	2.88 (2.60-3.19)	3.48 (3.12-3.86)	3.96 (3.53-4.39)	4.47 (3.95-4.95)	4.99 (4.39-5.54)	5.72 (4.96-6.37)	6.30 (5.42-7.03)
3-day	1.63 (1.49-1.80)	2.06 (1.88-2.27)	2.64 (2.40-2.91)	3.10 (2.82-3.42)	3.75 (3.38-4.13)	4.26 (3.82-4.69)	4.80 (4.28-5.29)	5.36 (4.74-5.92)	6.14 (5.37-6.80)	6.75 (5.86-7.50)
4-day	1.75 (1.61-1.93)	2.21 (2.03-2.43)	2.83 (2.59-3.10)	3.33 (3.04-3.65)	4.01 (3.64-4.40)	4.55 (4.11-5.00)	5.13 (4.61-5.64)	5.72 (5.10-6.30)	6.55 (5.78-7.24)	7.20 (6.30-7.97)
7-day	2.08 (1.91-2.30)	2.63 (2.40-2.91)	3.35 (3.06-3.71)	3.94 (3.58-4.35)	4.75 (4.29-5.24)	5.38 (4.84-5.93)	6.04 (5.41-6.67)	6.72 (5.97-7.43)	7.66 (6.73-8.50)	8.40 (7.32-9.35)
10-day	2.30 (2.11-2.53)	2.91 (2.67-3.20)	3.74 (3.41-4.10)	4.39 (3.99-4.81)	5.27 (4.78-5.79)	5.96 (5.37-6.54)	6.68 (5.99-7.34)	7.42 (6.61-8.17)	8.43 (7.43-9.29)	9.22 (8.05-10.2)
20-day	2.89 (2.64-3.17)	3.67 (3.36-4.02)	4.68 (4.27-5.13)	5.45 (4.98-5.98)	6.50 (5.91-7.13)	7.30 (6.61-8.01)	8.12 (7.31-8.92)	8.94 (8.01-9.84)	10.0 (8.93-11.1)	10.9 (9.63-12.1)
30-day	3.50 (3.21-3.82)	4.44 (4.06-4.84)	5.62 (5.13-6.14)	6.53 (5.95-7.12)	7.72 (7.00-8.42)	8.62 (7.79-9.41)	9.53 (8.58-10.4)	10.4 (9.35-11.4)	11.6 (10.3-12.8)	12.5 (11.1-13.8)
45-day	4.19 (3.81-4.61)	5.29 (4.80-5.83)	6.65 (6.03-7.33)	7.68 (6.95-8.47)	9.04 (8.15-9.96)	10.1 (9.04-11.1)	11.1 (9.90-12.2)	12.1 (10.8-13.3)	13.4 (11.8-14.9)	14.4 (12.7-16.0)
60-day	4.78 (4.34-5.26)	6.05 (5.48-6.65)	7.61 (6.89-8.38)	8.79 (7.93-9.67)	10.3 (9.26-11.4)	11.5 (10.2-12.6)	12.6 (11.2-13.9)	13.7 (12.2-15.2)	15.2 (13.4-16.9)	16.3 (14.3-18.2)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

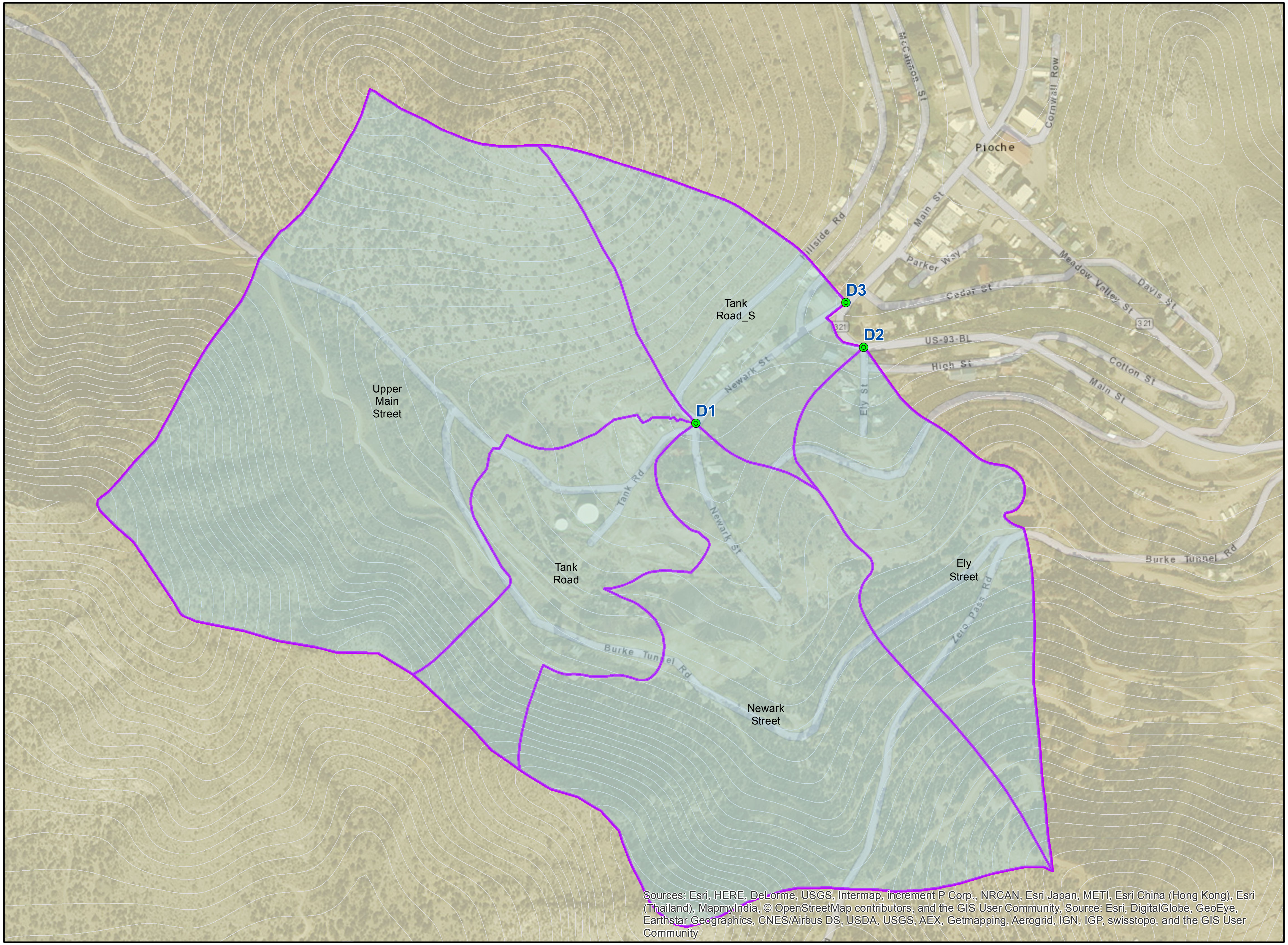



PDS-based depth-duration-frequency (DDF) curves

Latitude: 37.9249°, Longitude: -114.4557°

Attachment B: Subbasin Map

Jan 25, 2016 jstultz
File: [\\BCCARFP01\Projects] S:_147937 Temp Working Folder jstultz\MXD\SiteMap_wking_17x11_123015.mxd



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

● Discharge Assessment Points

Subbasins

Contour- 20'

Brown AND Caldwell

Greenfield Environmental Multistate Trust, LLC.

Date: Jan 2016

Project: 147937

N
W E
S

0 140 280 560
Feet

Exhibit D

Subbasins Map

Caselton Mine

HEC-HMS Modeling Study

Attachment C: Sediment Bulking Calculations

Below is “Equation 1” from Gartner, Cannon and Helsel (2009), the equation selected for final sediment bulking calculation results:

$$\log(V) = 2.2 + 0.7\log(R) + 0.1\sqrt{B} + 0.3LE + 0.5\log(A) + 0.02S - 2.1RR + 0.5^2 * 0.5$$

where:

$V = sediment\ yield\ (m^3)$

$R = peak\ 1\ hour\ rainfall\ depth\ (mm)$

$B = burned\ area\ in\ last\ fire\ (km^2)$

$LE = Lingering\ Effect = e^{-0.5t};\quad t = years\ since\ last\ fire$

$A = basin\ area\ (km^2)$

$S = average\ basin\ slope\ (\%)$

$RR = Relief\ Ratio$

The input parameter estimates are tabulated in the table below. Basin area and average slope were calculated using geospatial data of the Caselton Mine site, coordinating to the delineated basins of the hydrologic model. The relief ratio, RR, was calculated as the following equation:

$$RR = \frac{Maximum\ Elevation\ - Minimum\ Elevation}{Maximum\ Overland\ Flow\ Length}$$

Calculation A- 1 Input Parameter Estimates

Input Parameter Estimates			
Basin ID	Basin Area (km^2)	Average Slope (%)	Relief Ratio
Ely	0.073	28	0.27
Newark	0.163	39	0.31
Tank	0.062	30	0.31
Tank_S	0.060	32	0.31
Upper	0.223	39	0.29
Out	0.391	29	0.17

The peak 1 hour rainfall depth, R, was found using the design storm rainfall distribution. These values apply to each basin, as each basin was given the same design storm. The R values are tabulated in the table below.

Calculation A- 2 Peak 1-hour Rainfall Depth

Wild Fire History Parameter Selections

Storm	R (mm)
5-YR	23.9
10-YR	28.0
25-YR	33.8
50-YR	38.5
100-YR	43.1
200-YR	48.1
500-YR	54.8

The parameters related to wild fire history, burned area (B) and “lingering effect” (LE), were estimated with a sensitivity analysis, because of the lack of wild fire history information at the Caselton Mine site. The values selected for the final calculation are tabulated in the table below. The selected values coordinate to a 100% burn occurring 10 years prior. Lingering effect was calculated using the follow equation:

$$LE = e^{-0.5t} = e^{-0.5*(10\ years)} = 0.007$$

Calculation A- 3 Wild Fire History Parameter Selections

Wild Fire History Parameter Selections

Basin ID	B (km^2)	LE
Ely	0.073	0.007
Newark	0.163	0.007
Tank	0.062	0.007
Tank_S	0.060	0.007
Upper	0.223	0.007
Out	0.391	0.007

The final sediment yield values are tabulated in the table below.

Table 10. Summary of Sediment Bulking Volumes

Basin or Discharge Point	Sediment Volume (acre-feet)						
	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Upper Main Street	0.7	0.8	0.9	1.0	1.1	1.2	1.3
Tank Road	0.4	0.42	0.5	0.5	0.6	0.6	0.7
Newark Street	1.0	1.1	1.2	1.3	1.4	1.6	1.7
Ely Street	0.5	0.5	0.6	0.6	0.7	0.7	0.8
Tank Road_S	0.4	0.5	0.5	0.6	0.6	0.7	0.7
Out	1.78	2.0	2.3	2.5	2.7	2.9	3.2
D1	2.1	2.3	2.6	2.9	3.1	3.4	3.7
D2	0.5	0.5	0.6	0.6	0.7	0.7	0.8
D3	2.9	3.3	3.7	4.1	4.4	4.8	5.2
D4	4.7	5.2	6.0	6.6	7.1	7.7	8.4

Attachment D: HEC-HMS Model Output

HEC-HMS Model Results for 500-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	148.7	01Nov2015, 12:00	10.0
Newark	0.063	133.6	01Nov2015, 12:00	8.2
Tank	0.024	64.3	01Nov2015, 11:55	4.0
D1	0.173	346.4	01Nov2015, 12:00	22.2
Ely	0.028	65.1	01Nov2015, 12:00	4.1
D2	0.028	65.1	01Nov2015, 12:00	4.1
Tank_S	0.023	62.8	01Nov2015, 12:00	4.0
D3	0.224	474.2	01Nov2015, 12:00	30.3
Out	0.155	347.3	01Nov2015, 12:05	27.5
D4	0.379	788.5	01Nov2015, 12:00	57.8

HEC-HMS Model Results for 200-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	116.8	01Nov2015, 12:00	7.9
Newark	0.063	107.6	01Nov2015, 12:00	6.6
Tank	0.024	53.6	01Nov2015, 12:00	3.3
D1	0.173	278.0	01Nov2015, 12:00	17.8
Ely	0.028	53.3	01Nov2015, 12:00	3.4
D2	0.028	53.3	01Nov2015, 12:00	3.4
Tank_S	0.023	52.7	01Nov2015, 12:00	3.3
D3	0.224	384.0	01Nov2015, 12:00	24.5
Out	0.155	292.0	01Nov2015, 12:05	23.0
D4	0.379	646.9	01Nov2015, 12:00	47.5

HEC-HMS Model Results for 100-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	94.4	01Nov2015, 12:00	6.5
Newark	0.063	89.2	01Nov2015, 12:00	5.4
Tank	0.024	46.1	01Nov2015, 12:00	2.9
D1	0.173	229.7	01Nov2015, 12:00	14.8
Ely	0.028	44.9	01Nov2015, 12:00	2.8
D2	0.028	44.9	01Nov2015, 12:00	2.8
Tank_S	0.023	45.4	01Nov2015, 12:00	2.8
D3	0.224	319.9	01Nov2015, 12:00	20.4
Out	0.155	251.8	01Nov2015, 12:05	19.8
D4	0.379	545.5	01Nov2015, 12:00	40.2

HEC-HMS Model Results for 50-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	74.1	01Nov2015, 12:00	5.2
Newark	0.063	72.1	01Nov2015, 12:00	4.4
Tank	0.024	39.0	01Nov2015, 12:00	2.4
D1	0.173	185.2	01Nov2015, 12:00	12.0
Ely	0.028	37.0	01Nov2015, 12:00	2.3
D2	0.028	37.0	01Nov2015, 12:00	2.3
Tank_S	0.023	38.4	01Nov2015, 12:00	2.4
D3	0.224	260.6	01Nov2015, 12:00	16.7
Out	0.155	213.7	01Nov2015, 12:05	16.7
D4	0.379	451.0	01Nov2015, 12:00	33.4

HEC-HMS Model Results for 25-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	55.3	01Nov2015, 12:00	4.0
Newark	0.063	56.2	01Nov2015, 12:00	3.5
Tank	0.024	32.1	01Nov2015, 12:00	2.0
D1	0.173	143.6	01Nov2015, 12:00	9.4
Ely	0.028	29.5	01Nov2015, 12:00	1.9
D2	0.028	29.5	01Nov2015, 12:00	1.9
Tank_S	0.023	31.7	01Nov2015, 12:00	1.9
D3	0.224	204.9	01Nov2015, 12:00	13.2
Out	0.155	177.0	01Nov2015, 12:05	13.8
D4	0.379	361.4	01Nov2015, 12:00	27.0

HEC-HMS Model Results for 10-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	34.0	01Nov2015, 12:00	2.6
Newark	0.063	37.5	01Nov2015, 12:00	2.4
Tank	0.024	23.8	01Nov2015, 12:00	1.4
D1	0.173	95.2	01Nov2015, 12:00	6.4
Ely	0.028	20.6	01Nov2015, 12:00	1.3
D2	0.028	20.6	01Nov2015, 12:00	1.3
Tank_S	0.023	23.5	01Nov2015, 12:00	1.4
D3	0.224	139.4	01Nov2015, 12:00	9.2
Out	0.155	132.0	01Nov2015, 12:05	10.3
D4	0.379	254.7	01Nov2015, 12:00	19.5

HEC-HMS Model Results for 5-yr, 24hr Event

Hydrologic Element	Drainage Area (Mi^2)	Peak Discharge (cfs)	Time of Peak	Volume (ac-ft)
Upper	0.086	21.2	01Nov2015, 12:05	1.8
Newark	0.063	25.2	01Nov2015, 12:00	1.6
Tank	0.024	18.0	01Nov2015, 12:00	1.1
D1	0.173	63.6	01Nov2015, 12:00	4.5
Ely	0.028	14.6	01Nov2015, 12:00	1.0
D2	0.028	14.6	01Nov2015, 12:00	1.0
Tank_S	0.023	17.8	01Nov2015, 12:00	1.1
D3	0.224	96.1	01Nov2015, 12:00	6.6
Out	0.155	100.6	01Nov2015, 12:05	7.9
D4	0.379	182.9	01Nov2015, 12:00	14.5

Attachment E: Peak Discharge Calculations

Peak Discharge Calculations Using Regression Equations for Region 6

Regression equations are in the following form:

$$Q_T = A * Area^a (ELEV/1000)^{-b}$$

where:

A = regression equation coefficient
a = regression equation exponent
b = regression equation exponent

USGS Peak Discharge Regression Equations for Region 6 in Nevada.

Recurrence, yrs	Regression Equation
5	$Q5 = 32 * Area^{0.80} (ELEV/1000)^{-0.66}$
10	$Q10 = 590 * Area^{0.62} (ELEV/1000)^{-1.6}$
25	$Q25 = 3{,}200 * Area^{0.62} (ELEV/1000)^{-2.1}$
50	$Q50 = 5{,}300 * Area^{0.64} (ELEV/1000)^{-2.1}$
100	$Q100 = 20{,}000 * Area^{0.51} (ELEV/1000)^{-2.3}$

Equations are from Table 2 of the USGS National Flood-Frequency Program Methods guidance.

Source: USGS (United States Geological Survey). 1998. The National Flood-Frequency Program - Methods for Estimating Flood Magnitude and Frequency in Rural Areas in Nevada.

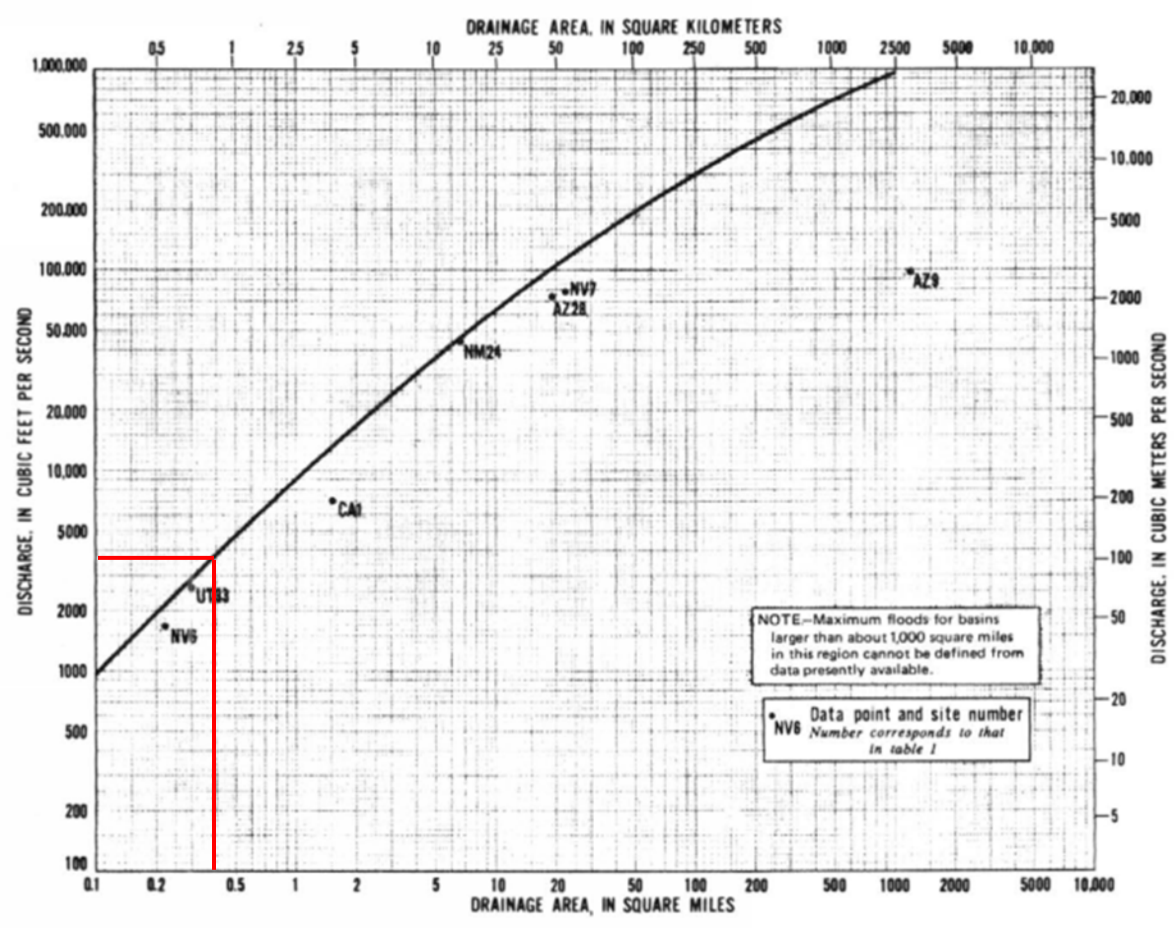
Site Characteristics

Site ID =	Town of Pioche
Lat/Long =	37.9249/ -114.4557
Site Area, sq mi =	0.379
Elevation, ft =	6340

Estimated USGS Peak Discharges for Site Drainage Area

Recurrence Interval, Q_{yrs}	Peak Discharge, cfs
Q_5	4.4
Q_{10}	16.8
Q_{25}	36.3
Q_{50}	58.9
Q_{100}	174.3

Attachment F: Envelope Curve for Region 16



Peak Discharge versus drainage area and envelope curve for region 16. (Crippen and Bue 1977)